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Fertilizers for Potatoes in the Red River Valley

Marshall County field showing growth of potatoes on fertilized plot (left) and unfertilized plot (right)

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★ THE POTATO is one of the chief cultivated crops grown in the Red River Valley. As a crop it fits well in a rotation with small grains and legumes. For its best development the crop requires a good supply of soil moisture and well-drained soil conditions. Under poor drainage it tends to produce watery tubers of undesirable quality. Potatoes require liberal amounts of plant food and, when moisture conditions are favorable, often respond well to generous applications of available plant-food constituents. Since large amounts of carbohydrate material, especially starch and sugar, are produced, the crop requires relatively large amounts of potassium.

Cooperative experiments to determine the effect of commercial fertilizers on the growth, yield, and market grade of potatoes have been in progress in the Red River Valley since 1939. The trials were conducted in cooperation with growers located in Clay, Norman, Polk, and Marshall counties. In Norman and Polk counties trials were made in five seasons, in Clay in four, and in Marshall in one season. All the experiments were located in large fields, and the plots were planted with the same seed and given the same cultivation and spray treatments as the remainder of the field.

The results obtained in four seasons—1939, 1941, 1942, and 1943—are reported. In 1940 the experiments were limited to the study of the effect of the inclusion of potash in the fertilizer, and no information was obtained on the effect of phosphate alone as compared to unfertilized land. Since the effect of potash in that season was similar to its effect in the four other seasons, the data for that year are omitted from this bulletin.

Daily records of precipitation were kept at most of the farms on which fertilizer trials were in progress. Records were also made available through the courtesy of other growers and local elevators. As would be expected, potato yields on the experimental fields were considerably affected by the amount and distribution of rainfall.

Soil Type Characteristics

Trials with fertilizer were made on six soil types—Fargo clay, Fargo silty clay, Bearden silt loam, Bearden loam, Grimstad fine sandy loam, and Ulen loamy sand. In reporting the results from the experiments, the first three types were combined and are referred to as heavy-textured soils. The Bearden loam, the Grimstad fine sandy loam, and Ulen loamy sand are grouped as light-textured soils. The distribution of the different soil types in the Red River Valley is shown on maps included in the soil survey bulletin entitled "The Red River Valley Area—Minnesota." Copies of this publication may be ob-

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tained from county agents or from representatives in Congress. The heavy-textured soils are most commonly found adjacent to the Red River, while the light-textured are more generally exposed along the eastern side of the Valley.

The soils of the light-textured group are sandy and have a lower water-holding capacity than those of the heavy-textured group. Limited amounts of soluble salts occur in places in both groups and both are well supplied with organic matter. The lime supply in both soil groups is high. On a considerable part of the fields free lime occurs in the surface soil as well as in the subsoil. Calcium sulfate or gypsum is commonly present but varies in amount. It occurs more commonly in the light-textured soils than in the soils of the other group.

Calculation of Significant Differences Due to Fertilization

Yield of potato tubers, tuber number, tuber weight, market grade, and yield of tops are based on replicated plots. All fertilizer treatments were replicated three or four times on each field and the figures reported in subsequent tables are averages of yields from these replicated plots.

The responses to a given treatment on different fields will vary, owing to such things as soil differences, differences in tillage, differences in cropping, and other factors. For crop yields from a given field or a group of fields, mathematical methods have been devised by which the influence of various controlled factors may be calculated. Variations in crop yields due to factors which cannot be controlled make up "experimental error." If the effect of a fertilizer treatment is appreciably greater than the experimental error, the increase in yield is said to be significant. The amount of increase required before any treatment is significant has been calculated and is shown in the yield tables which follow as "significant difference." All increases great enough to be significant are marked with an asterisk (*). More than one treatment may show a significant increase. In such cases the greatest increase is the most significant.

Effects of Fertilizers

Yield of Potatoes

The experiments in the first year, 1939, included trials with superphosphate (P) alone, superphosphate and potash (PK), and nitrogen, superphosphate, and potash (NPK). Nitrogen was supplied in the form of sulfate of ammonia, superphosphate as 20 per cent or 43 per cent superphosphate, and potash as muriate of potash. The phosphate was applied with a fertilizer attachment to the planter. Either 43 per cent superphosphate at approximately 100 pounds or 20 per cent superphosphate at approximately 200 pounds per acre was used. The nitrogen fertilizer was spread broadcast as a top dressing at the rate of 100 pounds per acre immediately following planting. On a part of the fields the potash was applied with a planter attachment at the rate of 100 pounds per acre, and on the others it was spread broadcast at 200 pounds per acre as a top dressing immediately after the potatoes were planted. A study of the data indicates that the potash is equally effective when applied in either way. Both sulfate of ammonia and muriate of potash are water soluble and are carried into the soil by rainwater. The treated areas were at least four rows in width and extended the full length of the field. An unfertilized or check strip was left on each field so that the increase in

yield from each fertilizer could be determined.

The rainfall during the latter half of May in 1939 (figure 1) was very low, and only moderate amounts fell in June. All of July and the first half of August were dry but the fields on heavy-textured soils received adequate amounts of moisture in late August and early September. The areas of light-textured soils continued dry throughout the season. As a result, yields of potatoes were somewhat better on the heavy-textured soils. Owing to the dryness of the season, yields on both soil groups were lower than in the subsequent years.

All of the 10 fields in 1939 showed significant increases in yield of marketable potatoes to some fertilizer treatment (table 1). Marketable tubers were those 1⅞ inches or more in diameter. On one of the five heavy-textured fields, superphosphate alone produced the greatest increase. On three others, highest yields were obtained with the phosphate-potash mixture, while on the remaining one the complete fertilizer gave the best return.

The five fields on light-textured soils in 1939 responded to fertilizer treatment in the same manner as the heavy-textured soils—one field showed

Table 1. Comparative Yields of Marketable Potatoes Obtained by Different Fertilizer Treatments on Five Fields of Heavy-textured and Five Fields of Light-textured Soils in 1939

Fields showing	Number of fields	Per cent of total fields	Yield from unfertilized	Increase from †					
				P	PK	NPK	P	PK	NPK
				Bushels per acre			Per cent		
HEAVY-TEXTURED SOILS									
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	1	20	112	27*	5	14	24	4	13
Greatest response to PK	3	60	122	3	27*	6	2	22	5
Greatest response to NPK	1	20	181	26*	24*	62*	14	13	34
LIGHT-TEXTURED SOILS									
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	1	20	95	22*	22*	20*	23	23	21
Greatest response to PK	3	60	83	14*	43*	7	17	52	8
Greatest response to NPK	1	20	98	28*	59*	75*	30	60	76

* Significant difference. Increases required for significance at the 5 per cent level: heavy-textured soils, 21.1 bushels; light-textured soils, 12.1 bushels.

† P = Phosphate.
PK = Phosphate and Potash.
NPK = Nitrogen, Phosphate, and Potash.

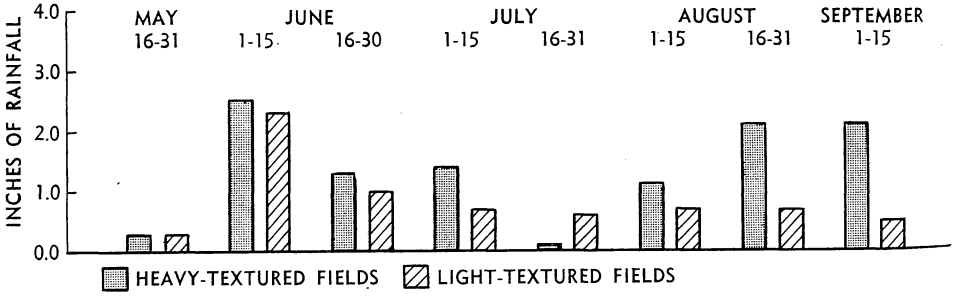

FIG. 1. Average rainfall during crop season of 1939 in Red River Valley soil areas

the greatest increase from phosphate alone, three from the phosphate-potash mixture, and one from complete fertilizer. While the yields were lower on the light-textured soils, the percentage increases from fertilizer were generally higher than on those with heavy texture (table 1). The three fields showing greatest response to the phosphate-potash mixture gave an average increase of 52 per cent. On the one field giving the greatest response to the complete fertilizer, the phosphate-potash combination gave an increase of 60 per cent. Thus the phosphate-potash mixture appeared to offer an opportunity for increasing the yield of potatoes on a majority of fields on both groups of soils.

The inclusion of nitrogen in the fertilizer was without effect on eight of the 10 fields. Field tests during the growing season showed the plants on all treatments, including the unfertilized plots, to be well supplied with nitrates. Because of the limited response to nitrogen fertilizer and the exceptionally high nitrogen content of the soils of the Red River Valley, nitrogen fertilizers were not included in the trials in subsequent years. Some growers in the Red River Valley are using fertilizers containing nitrogen. There is a possibility that the inclusion of nitrogen in the fertilizer may serve as a "starter" and cause a more rapid growth of the potato plants in the early part of the season. This would permit of earlier cultivation and thereby aid in weed control. Experiments were initiated in the spring of 1944 to study further the effect of nitrogen fertilizers on the yield of potatoes in the Red River Valley.

The experiments in 1941 were of the same general pattern as those in 1939. The treatments used were superphosphate alone and superphosphate and muriate of potash. The method of application and rates were the same as in 1939.

During the growing season of 1941, rainfall was generally higher and better distributed than in 1939 (figure 2). The last half of May was dry, but a relatively large amount of rain fell during the first half of June and moderate amounts in the last half. July was dry—only one inch falling during the entire month. During the first two weeks of August, however, four inches fell and ample quantities during the last two-week period of that month and the first half of September. Under these favorable conditions of rainfall, yields of potatoes were generally good.

The trials in 1941 were made on 11 fields of heavy-textured and seven fields of light-textured soils, none of which had been used in the 1939 trials. Four of the 18 fields failed to respond to any fertilizer treatment—three on heavy and one on light-textured soil (table 2). Approximately one fourth of the fields on both soil groups, 27 and 29 per cent respectively, gave greatest increases with superphosphate alone. Roughly half of the fields in both groups showed maximum increases with the phosphate-potash mixture. A higher percentage of light-textured soils was responsive to fertilizer, and the increase in yield from the phosphate-potash mixture was more marked. The increase in yield on the lighter-textured group was 37 per cent as compared to 12 per cent for the heavy-textured soils.

The results in 1941 differed from those in 1939 in that one fourth of the fields showed no response to fertilizer and a slightly lower percentage of fields gave significant increases with the phosphate-potash mixture. When fields were selected for experiments, previous treatments with manure or commercial fertilizers were not taken into consideration since the use of one or the other or both for the potato crop is a practice followed by many growers. It was found, however, that, in many instances, there is a residual effect of commercial fertilizer on the succeeding grain crop.

Table 2. Comparative Yields of Marketable Potatoes Obtained by Different Fertilizer Treatments on 11 Fields of Heavy-textured and Seven Fields of Light-textured Soils in 1941

Fields showing	Number of fields	Per cent of total fields	Yield from unfertilized	Increase from			
				P	PK	P	PK
			——Bushels per acre——			Per cent	
HEAVY-TEXTURED SOILS							
No response to fertilizer	3	27	235	0	2	0	0
Greatest response to P	3	27	150	32*	23*	21	15
Greatest response to PK	5	46	193	0	23*	0	12
LIGHT-TEXTURED SOILS							
No response to fertilizer	1	14	99	3	9	3	9
Greatest response to P	2	29	126	23*	17	18	13
Greatest response to PK	4	57	108	0	47*	0	37

* Significant difference. Increases required for significance at the 5 per cent level: heavy-textured soils, 12.1 bushels; light-textured soils, 17.9 bushels.

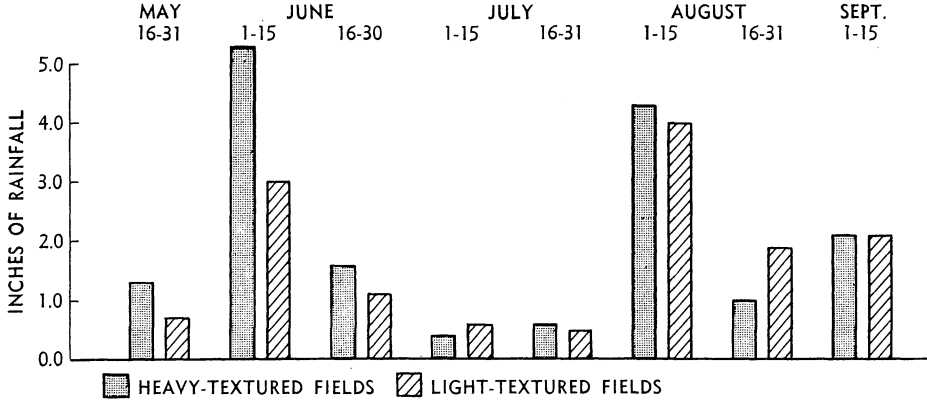

FIG. 2. Average rainfall during crop season of 1941 in Red River Valley soil areas

There is a probability that such residual effects may extend to the second and possibly the third crop following relatively heavy applications of fertilizer. If this should be the case, it offers a possible explanation of the lack of response to fertilizer treatment on some of the fields used in 1941 and subsequent years.

The amounts of rainfall in the growing season of 1942 were moderate to low between May 15 and August 15 (figure 3). The first half of July was very dry, only one-half inch of rain falling in the two-week period, but the amount in the last half of the month rose to approximately one inch. A similar amount fell during the first half of August. The last half of that month was wet, four inches falling in the two-week period. This was followed by a dry period during the first half of September. The August rains insured a good yield of potatoes even though June and July had been somewhat dry.

In the 1942 season a third treatment was added—a mixture of superphosphate and manure salts. Manure salts consist of a mixture of unrefined minerals carrying from 22 to 32 per cent of potash (K_2O). The material used in these experiments contained 31 per cent of potash (K_2O). In this season the manure salts were applied at the rate of

Table 3. Comparative Yields of Marketable Potatoes Obtained by Different Fertilizer Treatments on Six Fields of Heavy-textured and Six Fields of Light-textured Soils in 1942

Fields showing	Number of fields	Per cent of total fields	Yield from unfertilized	Increase from			
				P	PK	P	PK
			——Bushels per acre——			Per cent	
HEAVY-TEXTURED SOILS							
No response to fertilizer	0	0	.....	.....	.....	.....	.....
Greatest response to P	4	83	198	44*	38*	22	19
Greatest response to PK	2	17	222	26*	39*	12	17
LIGHT-TEXTURED SOILS							
No response to fertilizer	3	50	202	7	13	3	6
Greatest response to P	1	17	178	84*	87*	47	49
Greatest response to PK	2	33	220	37*	76*	17	35

* Significant difference. Increases required for significance at the 5 per cent level: heavy-textured soils, 15.4 bushels; light-textured soils, 25.5 bushels.

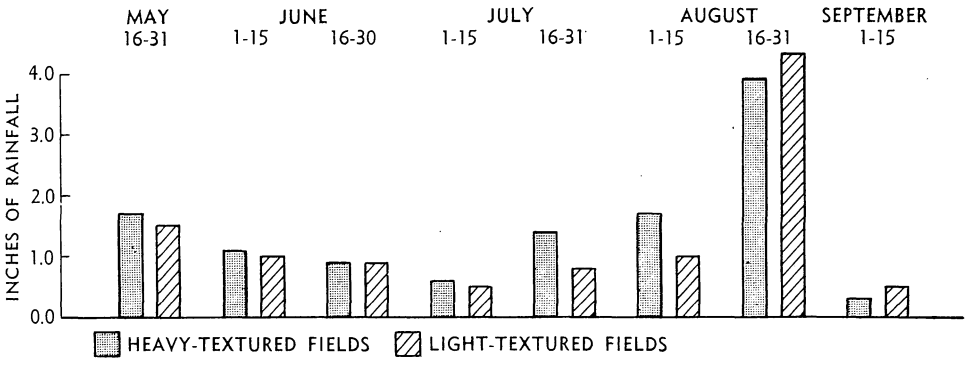

FIG. 3. Average rainfall during crop season of 1942 in Red River Valley soil areas

185 pounds per acre, giving an amount of chlorine equivalent to that in 200 pounds of 60 per cent muriate (chloride) of potash. The latter contained 120 pounds of potash (K_2O) as compared to 57 pounds of potash in the manure salts. Thus the amount of potash in the phosphate-manure salts treatment was slightly less than half that of the superphosphate-muriate of potash treatment.

There were six fields on heavy and six on light-textured soils in 1942. Of the six fields on heavy-textured soils, four gave the greatest increase in yield from the use of straight superphosphate, while two required the phosphate-potash combination (table 3). The increases were 22 and 17 per cent respectively.

On the light-textured soils three fields showed no increase in yield from the application of fertilizer. Of the three remaining fields one gave the highest yield with superphosphate and two with the phosphate-potash combination. The percentage increases were higher than on the heavy-textured soils and amounted to 47 and 35 per cent respectively for the phosphate and phosphate-potash treatments.

The 1943 treatments were further expanded to include muriate of potash alone (K) and manure salts alone (MS) in order to determine the effect of the two forms of potash without phosphate. In this season the rates of application

of the potash fertilizers were adjusted to give equivalent amounts of potash (K_2O) and consisted of muriate of potash at 200 pounds and manure salts at 387 pounds per acre.

The distribution of rainfall during the growing season of 1943 was better than in the other three seasons (figure 4). No excessive amount fell in any two-week period, and with the possible exception of the last half of June there was no exceptionally dry period. Ample amounts of moisture again fell during the month of August. Potato yields, on the average, were the highest obtained in the four years.

The experiments in 1943 included trials on nine fields of heavy- and on eight fields of light-textured soils. Of the heavy-textured group one field failed to show any response to fertilizer, four gave greatest response with straight phosphate, and four the greatest increase with a mixture of phosphate and potash (table 4). The percentage increases in yield were 19 and 22 respectively for phosphate alone and the phosphate-potash mixture. All of the eight fields of light-textured soils gave the highest yield with the mixture of phosphate and potash, the yields being increased 26 per cent on the average. Potash used alone was without effect on both groups.

The yield data for the four years are summarized in table 5 and figure 5. While increases from fertilizer treatments were not appreciably decreased

Table 4. Comparative Yields of Marketable Potatoes Obtained by Different Fertilizer Treatments on Nine Fields of Heavy-textured and Eight Fields of Light-textured Soils in 1943

Fields showing	Number of fields	Per cent of total fields	Yield from unfertilized	Increase from					
				P	PK	K	P	PK	K
				Bushels per acre			Per cent		
HEAVY-TEXTURED SOILS									
No response to fertilizer	1	12	293	0	10	1	0	4	0
Greatest response to P	4	44	239	46*	32*	17	19	13	7
Greatest response to PK	4	44	244	36*	54*	10	15	22	4
Greatest response to K	0	0	.....	.....	.....	.....	.....	.....	.....
LIGHT-TEXTURED SOILS									
No response to fertilizer	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to P	0	0	.....	.....	.....	.....	.....	.....	.....
Greatest response to PK	8	100	192	3	51*	20*	1	26	10
Greatest response to K	0	0	.....	.....	.....	.....	.....	.....	.....

* Significant difference. Increases required for significance at the 5 per cent level: heavy-textured soils, 17.8 bushels; light-textured soils, 19.6 bushels.

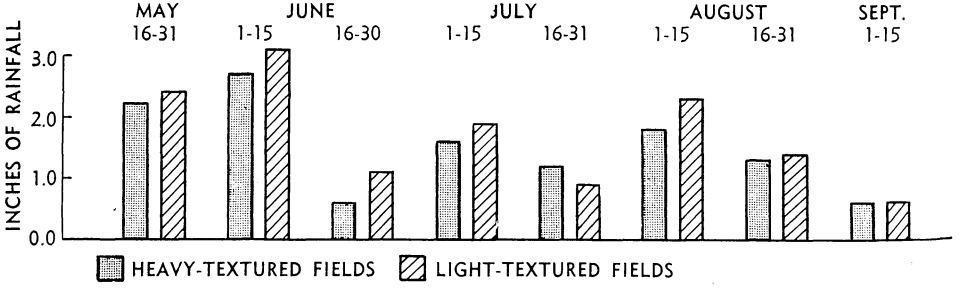

FIG. 4. Average rainfall during crop season of 1943 in Red River Valley soil areas

Table 5. Summary: Comparative Yields of Marketable Potatoes Obtained by Different Fertilizer Treatments on 30 Fields of Heavy-textured and 25 Fields of Light-textured Soils in the Four Seasons

Fields showing	Number of fields	Per cent of total fields	Average increase from			
			P	PK	P	PK
			Bushels per acre		Per cent	
HEAVY-TEXTURED SOILS						
No response to fertilizer	4	13	0	4	0	1
Greatest response to P	12	40	40	29	21	15
Greatest response to PK	14	47	15	35	7	18
LIGHT-TEXTURED SOILS						
No response to fertilizer	4	16	8	9	3	5
Greatest response to P	4	16	38	36	27	25
Greatest response to PK	17	68	8	51	6	32

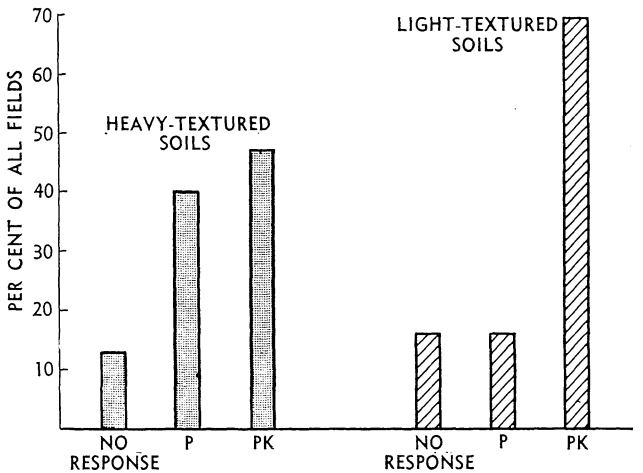

FIG. 5. Percentage of 30 heavy-textured and of 25 light-textured fields showing greatest increases in yield to different fertilizer treatments

by the dry season of 1939, it should be noted that with the early and midseason potato varieties grown in the Red River Valley, the month of August appears to be a critical one in so far as rainfall is concerned. Yields were good when August rainfall was ample. Trials were made on 30 different fields of heavy-textured soils. Of these only four fields (13 per cent) failed to respond to some fertilizer treatment. Twelve (40 per cent) of the fields gave the greatest response to superphosphate alone and the increase amounted to an average of 40 bushels per acre (21 per cent) of marketable potatoes. Fourteen (47 per cent) of the fields produced maximum yields with the phosphate-potash mixture, the average increase being 35 bushels per acre.

On the light-textured soils four of the 25 fields gave no significant increase in yield from fertilizer treatment. On another four fields largest increases were obtained with phosphate alone, the increase amounting to 38 bushels

per acre (27 per cent). On the 17 remaining fields the phosphate-potash mixture produced the maximum increase, amounting to an average of 51 bushels per acre.

It is to be noted that on the light-textured soils the inclusion of potash in the fertilizer mixture is generally more beneficial than on the heavy-textured soils, although half of the latter gave maximum yields only when potash was included in the mixture. It is clear that the majority of the fields on both groups of soils will give maximum yields only when a phosphate-potash mixture is used.

Market Grade of Potatoes

The yield of potatoes may be influenced by fertilizer in several ways. There may be an increase in the size of tubers, in the number of tubers, or an increase in the percentage of marketable tubers with no increase or a decrease in percentage of culls.

The percentage of marketable tubers by weight is shown in table 6. On the heavy-textured soils fertilizer treatment had little effect on the percentage of marketable potatoes, the average for the four years from straight phosphate and the phosphate-potash mixture being almost identical with that of the unfertilized land.

In three of the four years fertilizer treatment increased the percentage of marketable tubers on the light-textured soils. The increases were not marked, but for these soils the trend seems to be toward an improved market grade.

Number and Size of Potatoes

The effect of fertilizer on number of marketable potatoes and upon the tuber weight was studied in only one season—1943. The number of marketable tubers produced per acre under different fertilizer treatments is shown in table 7. The one field on heavy-textured soil which did not show a significant increase in yield from fertilizer did not show a *significant increase* in the number of marketable tubers although both phosphate and phosphate-potash were slightly effective, as indicated by an increase of 1,250 tubers. The four fields showing a yield response to phosphate also showed a significant increase in the number of tubers both from the phosphate and phosphate-potash treatments, but the increase was distinctly greater from the phosphate treatment. There was likewise a significant increase in the number of tubers on the four fields requiring the phosphate-potash mixture for maximum yields. On these the phosphate-potash mixture produced distinctly higher numbers than phosphate alone—the increases being 5,000 for phosphate and 6,252 for the mixture.

The eight fields on the light-textured

Table 6. Percentage of Marketable Potatoes Obtained by Different Fertilizer Treatments in the Four Seasons

Treatment	1939	1941	1942	1943	Average
	Per cent	Per cent	Per cent	Per cent	Per cent
HEAVY-TEXTURED SOILS					
Unfertilized	91.4	87.8	90.4	85.4	88.7
P	88.8	86.8	90.9	87.1	88.2
PK	91.5	86.2	89.9	87.7	88.8
LIGHT-TEXTURED SOILS					
Unfertilized	80.2	84.6	86.7	79.3	82.7
P	83.7	84.8	88.3	80.0	84.2
PK	86.8	83.5	88.0	83.8	85.5

Table 7. Number of Marketable Potatoes Obtained by Different Fertilizer Treatments on Nine Fields of Heavy-textured and Eight Fields of Light-textured Soils in 1943

Fields showing	Number of fields	Per cent of fields	Tubers per acre, unfertilized	Increase from			
				P	PK	P	PK
			Number			Per cent	
HEAVY-TEXTURED SOILS							
No response to fertilizer	1	12	49,599	1,250	1,250	2.5	2.5
Greatest response to P	4	44	45,014	7,500*	5,627*	16.7	12.5
Greatest response to PK	4	44	37,512	5,000*	6,252*	13.3	16.7
LIGHT-TEXTURED SOILS							
No response to fertilizer	0	0	.....	.....	.....	.....	.....
Greatest response to P	0	0	.....	.....	.....	.....	.....
Greatest response to PK	8	100	35,428	3,126*	8,753*	8.8	24.7

* Significant difference. Difference required for significance at 5 per cent level: heavy-textured soils, 1,800; light-textured soils, 2,700.

soils all gave maximum increases in yield with the phosphate-potash mixture (table 7). The effectiveness of the potash in the mixture is shown by the increase in the number of tubers. The phosphate-potash treatment gave an increase of 8,753 tubers per acre over the untreated plot as compared to 3,126 tubers from phosphate alone.

To study the effect of fertilizer treatment on the size of potatoes, the average tuber weight from the differently treated plots was determined (table 8). The effect of fertilizer on tuber weight or size was less marked than on the number of tubers. There was no significant increase in size except on those fields which gave the greatest increase from the phosphate-potash treatment. On the four fields with heavy texture which gave the greatest response to phosphate alone there was no significant increase in size of tubers.

It appears from the data that the increase in yield from fertilizers is accounted for chiefly in an increase in the number of marketable potatoes rather than in an increase in the size of the tubers. This is especially true on the light-textured soils where the size was only slightly affected but where the number was definitely increased.

Cooking Quality of Potatoes

Potatoes grown in 1942 and 1943 were subjected to cooking tests including both boiling and baking. In rating the cooked

Table 8. Average Weight in Grams† of Marketable Potatoes Obtained by Different Fertilizer Treatments on Nine Fields of Heavy-textured and Eight Fields of Light-textured Soils in 1943

Fields showing	Number of fields	Per cent of fields	Average weight of tubers on unfertilized	Increase from			
				P	PK	P	PK
			Grams			Per cent	
HEAVY-TEXTURED SOILS							
No response to fertilizer	1	12	160	0	8	0	5.0
Greatest response to P	4	44	144	−2	4	−1.4	2.8
Greatest response to PK	4	44	171	11*	14*	6.4	8.2
LIGHT-TEXTURED SOILS							
Response to PK	8	100	141	−2	11*	−1.4	7.8

* Significant difference. Difference required for significance at 5 per cent level: heavy-textured soils, 9 grams; light-textured soils, 9 grams.

† One gram = approximately 1/28 oz.

potatoes they were scored for color, mealiness, and flavor on the basis that a score of 4 was perfect for each of the three quality factors. Thus a score of 12 becomes the maximum rating. The quality scores given in table 9 are averages for ratings of potatoes from six fields of heavy-textured and eight fields of light-textured soils in 1942 and eight fields for each of the two groups of soils in 1943.

On the heavy soils the fertilizers, and particularly the phosphate-potash treatments, were associated with slight average increases in the cooking quality of the potatoes which approached significance in the case of the baking scores for the 1943 samples. On the light-textured soils the phosphate-potash treatments and especially the phosphate-manure salts combination caused significant increases in baking quality. The boiling tests showed significant increases in 1942 but not in 1943. In general, the light-textured soils are more deficient in the nutrient elements than those with heavy texture, and this probably accounts for the greater improvement in the cooking quality of the potatoes grown on fertilized land.

The results indicate that the inclusion of potash in the fertilizer mixture tends to improve the quality of potatoes grown in the Red River Valley. This is contrary to the findings of workers in the New England states who found that the inclusion of potash increased the yield but lowered the cooking quality.

Top Growth of Potatoes

The effect of fertilizer on the top growth of potatoes was determined in two years—1942 and 1943. The yield of tops in tons per acre is shown in table 10. In both years the moisture was adequate and well distributed and a maximum growth was probably obtained.

All fertilizer treatments produced an increase in top growth regardless of whether the yield of tubers was increased or not. Thus on the three fields of light-textured soils in 1942 and the one field of heavy-textured soil in 1943 which showed no increase in yield of marketable potatoes from fertilizer, both phosphate alone and the phosphate-potash mixture produced significant increases in the yield of tops. The appearance of the plants was suggestive of an increase in yield. With only one exception the phosphate-potash mixture was more effective than phosphate alone in promoting top growth. The exception occurred in 1943 on the four fields of heavy-textured soils on which phosphate produced the heaviest growth of tops.

Value of Different Potash Fertilizers

Three different potash fertilizers were tested in the experiments. These were 60 per cent muriate of potash, 50 per cent sulfate of potash, and manure salts carrying 31 per cent of potash (K_2O). The form commonly avail-

Table 9. Cooking Quality of Potatoes as Influenced by Fertilizer Treatment

Treatment	Heavy-textured soils				Light-textured soils			
	1942		1943		1942		1943	
	Boiled	Baked	Boiled	Baked	Boiled	Baked	Boiled	Baked
Unfertilized	9.75	8.75	8.58	8.82	8.81	8.13	8.67	8.16
P	9.92	8.58	9.01	8.87	9.75*	8.69	8.45	8.58
K—Muriate	.....	.....	9.02	9.01	.....	.....	8.56	8.62
PK—Muriate	10.17	8.92	9.12	9.27	9.63	8.94*	8.65	8.77*
PK—Manure salts	10.00	9.17	9.14	9.32	9.75*	9.75*	8.76	9.38*
Difference required for significance	1.04	0.90	0.90	0.53	0.90	0.80	0.90	0.53

* Significant difference. NOTE: A score of 12 was the maximum rating.

Table 10. Top Growth of Potatoes as Influenced by Fertilizer Treatment—Fields Arranged According to Response in Tuber Yields to Fertilizer Treatment

Response in tuber yield	Number of fields	Per cent of fields	Unfertilized	Gain from			
				P	PK	P	PK
			Tons per acre			Per cent	
1942—HEAVY-TEXTURED SOILS							
No response to fertilizer	0	0	.....	.....	.....	.....	.....
Greatest response to P	5	83	.99	.24*	.36*	24	36
Greatest response to PK	1	17	1.00	.09*	.21*	9	21
1942—LIGHT-TEXTURED SOILS							
No response to fertilizer	3	50	.87	.29*	.35*	33	40
Greatest response to P	1	17	.63	.16	.37*	25	59
Greatest response to PK	2	33	.73	.13	.43*	18	59
1943—HEAVY-TEXTURED SOILS							
No response to fertilizer	1	12	1.50	.39*	.47*	26	31
Greatest response to P	4	44	1.73	.20*	.11	12	6
Greatest response to PK	4	44	1.61	.20*	.24*	11	13
1943—LIGHT-TEXTURED SOILS							
No response to fertilizer	0	0	.....	.....	.....	.....	.....
Greatest response to P	0	0	.....	.....	.....	.....	.....
Greatest response to PK	8	100	1.18	.28*	.47*	24	40

* Significant difference.

able in Minnesota is the muriate of potash and for that reason it was used as the standard in all comparisons in all seasons. Manure salts consist of a mixture of natural potash minerals containing from 22 to 32 per cent of water-soluble potash. These salts are ground and mixed and passed into fertilizer trade channels with little refinement. In the production of muriate and sulfate of potash the salts are refined to increase the content of potash.

The three forms of potash fertilizer were tested on five fields in 1942 and on three fields in 1944. Trials in 1943 were limited to a comparison of the muriate with manure salts which were tested on 11 fields. The fertilizers were used alone and in combination with superphosphate. When used alone none of them significantly increased the yield of potatoes. It was only when they were combined with phosphate that significant increases were obtained. The effectiveness of the three forms as used in the Red River Valley experiments is shown in table 11. The data indicate that there is no significant difference between the three materials as a source of potash and that the three forms are equally satisfactory when rates are adjusted to give equivalent amounts of potash.

Minor or Trace Elements

In 1939 elaborate trials with the minor elements boron, zinc, manganese, iron, and copper were set up on 11

Table 11. Comparative Value of Muriate of Potash, Manure Salts, and Sulfate of Potash as a Source of Potash Measured in Yield Per Acre

Treatment	1942		1943		1944
	Yield	Tops	Yield	Tops	Yield
	Bushels	Tons	Bushels	Tons	Bushels
PK—Muriate	253	1.25	261	1.76	212
PK—Manure salts	257	1.23	262	1.74	197
PK—Sulfate	254	1.28	.....	.....	214

Table 12. Comparative Yields Per Acre of Marketable Potatoes Obtained with and without Boron in the Fertilizer Mixture

Treatment	1939 Yield per acre	1942	
		Yield	Tops
	Bushels	Bushels	Tons
PK	124	253	1.25
PK—Boron	124	262	1.19

fields and these were repeated on one field in 1942. The treatments included the minor elements singly and in combination with all fertilizer treatments. In addition, experiments with boron in combination with phosphate and potash were included in the trials in 1942 on six fields. The use of any of these minor elements either alone or in combination with fertilizer failed to increase the yield of potatoes significantly. The results obtained with and without boron in the fertilizer mixture are shown in table 12.

Residual Effect of Fertilizer

The potato crop in the Red River Valley is ordinarily followed by spring grain with which, in many cases, sweet clover is sown. The following year the sweet clover is plowed down in June and the land kept in clean fallow for the remainder of the season. On this potatoes or sugar beets are again planted. Thus the system is a three year rotation consisting of potatoes or sugar beets, grain, and sweet clover-fallow.

Fertilizers applied for potatoes may not be completely used, leaving some in the soil which may be utilized by the succeeding grain crop. In 1940 and again in 1942 and 1943 grain crops were harvested on plots receiving fertilizers for potatoes in the previous year. Since no additional fertilizer was applied, any increase was due to the residual effect of the fertilizer applied for potatoes. The results are reported in table 13.

There was, on the average, an increase in yield from the fertilizer. It is reasonably certain that increases in yield of 10 per cent or more are significant. The residual effect of phosphate on wheat on heavy-textured soils in 1942 was the only gain of less than 10 per cent. The largest increases in the yield of wheat were obtained with the phosphate-potash combination and this was true for both groups of soils. For this crop the inclusion of potash significantly increased the yield over phosphate alone.

In the two years in which barley was grown on the heavy-textured soils the greatest increases were obtained from phosphate alone. The inclusion of potash in the mixture gave markedly better yields of barley on the light-textured soils where the average increase on seven fields was 51.6 per cent as compared with 31.8 per cent for straight phosphate.

There was only one field of oats on the heavy-textured soil group. Definite conclusions cannot be drawn from the results on a single field, but the phosphate-potash combination appears to be more promising. The use of phosphate alone on the three fields on light-textured soils was as effective as the phosphate-potash mixture.

The yields of grains were definitely increased by the fertilizer applied in the preceding year for potatoes. It is clear that the entire cost of the fertilizer need not be charged to the potato crop since usually the following grain is also benefited. The increase in the yield of grain in a considerable number of cases was sufficient to cover the entire cost of the fertilizer.

Table 13. Residual Effects of Fertilizer on the Yields of Grain in the Red River Valley

Year	Crop	Number of fields	Yield from			Gain from			
			CK*	P	PK	P	PK	P	PK
			Bushels per acre					Per cent	
HEAVY-TEXTURED SOILS									
1940	Wheat	4	18.9	24.1	25.9	5.2	7.0	27.5	37.0
1942	Wheat	7	35.8	38.2	40.1	2.4	4.3	4.7	12.0
1943	Wheat	6	30.2	32.8	34.2	2.6	4.0	10.8	11.3
Average		17						12.2	17.6
1940	Barley	1	32.4	45.1	44.8	12.7	12.4	39.2	38.2
1942	Barley	3	50.6	57.2	57.0	6.6	6.4	13.0	12.6
Average		4						19.5	19.0
1943	Oats	1	72.0	79.8	93.4	7.8	21.0	15.2	29.7
LIGHT-TEXTURED SOILS									
1942	Wheat	2	27.2	30.4	30.4	3.2	3.2	11.7	11.7
1943	Wheat	2	23.6	26.8	32.2	3.2	8.6	13.5	36.4
Average		4						12.6	24.0
1940	Barley	2	19.2	32.1	34.7	11.9	15.5	61.9	80.7
1942	Barley	5	39.6	47.4	55.4	7.8	15.8	19.7	40.0
Average		7						31.8	51.6
1942	Oats	1	39.8	44.5	47.2	4.7	7.4	11.8	18.6
1943	Oats	2	42.8	57.0	54.6	14.2	11.8	33.1	27.5
Average		3						26.0	24.5

* Unfertilized.

Fertilizer Recommendations

The two groups of soils show rather distinct differences in their fertilizer requirements. The principal difference appears to lie in the relative importance of potash in the fertilizer mixture. Both groups require phosphate as a basic ingredient, but potash is relatively more important on the light-textured soils. Approximately 68 per cent of the fields of light-textured soils gave highest yields with the phosphate-potash mixture, whereas only 50 per cent of heavy-textured required this combination. Similarly, a relatively greater increase in yield was obtained on light-textured soils from the inclusion of potash in the mixture. This would indicate that more potash should be included in mixtures for light-textured soils.

Heavy-textured Soils

It is recommended that on the heavy-textured soils one of two fertilizer practices be followed: (a) apply 43 to 48 per cent superphosphate at 100 to 125 pounds or 20 per cent superphosphate at 200 to 250 pounds per acre with an attachment to the potato planter or (b) apply in the same manner a phosphate-potash mixture in which the phosphate-potash ratio is 2 to 1. Such mixtures would include 0-16-8, 0-20-10, and 0-30-15. An average application would consist of 60 to 70 pounds of plant food per acre. The pounds of plant food in 100 pounds of fertilizer are obtained by adding the figures of the fertilizer formula. Thus 100 pounds of 0-20-10 would contain 30 (20 + 10) pounds. To furnish 60 pounds of plant food it would then be necessary to apply 200 pounds per acre of the 0-20-10 fertilizer.

Where a phosphate-potash mixture is to be used, the two ingredients may be applied separately if desired. Wherever such a procedure is followed it is recommended that enough potash fertilizer be spread broadcast to furnish 60 to 75 pounds of K_2O. The fertilizer may be spread on plowed ground either in the fall or early spring and phosphate

be applied with the attachment to the planter as recommended in (a) above. When superphosphate is applied in the fall a part of the phosphate becomes fixed in the soil and is unavailable for the crop which is planted six or seven months later.

Light-textured Soils

The phosphate-potash mixture was most effective on approximately 70 per cent of the light-textured fields. In view of this it would appear that such a mixture should be employed on those fields to which fertilizer is to be applied. Since the potash is an essential constituent for these soils a 1 to 1 phosphate-potash ratio is recommended. Such mixtures would include the 0-12-12, 0-14-14, and 0-20-20 grades. An average application would consist of 60 to 70 pounds of plant food. At this rate 0-12-12 would be applied at approximately 275 pounds, 0-14-14 at 250 pounds, and 0-20-20 at 175 pounds per acre. The phosphate and potash may be applied separately if desired following the procedure described above for heavy-textured soils. If the potash is spread broadcast, enough fertilizer should be used to supply 80 to 90 pounds of K_2O.

Summary

The results of four years of trials with commercial fertilizers for potatoes in the Red River Valley are reported. Potatoes were grown on six soil types, three of which were heavy textured and three light textured. Treatments included superphosphate alone, phosphate and potash, and potash alone. In one season, 1939, nitrogen fertilizer was included.

On heavy-textured soils approximately 13 per cent of the fields did not respond to fertilizers, 40 per cent gave greatest increases in yield with superphosphate alone, and 47 per cent with a mixture of superphosphate and potash. On light-textured soils 16 per cent failed to respond to fertilizer, another 16 per cent gave maximum increases with straight phosphate, and 68 per cent with a mixture of phosphate and potash. Thus potash is of more importance in the fertilizer mixture for the light-textured soils.

Market grade of potatoes was not significantly affected by fertilizer treatment but the number of marketable potatoes was significantly increased. Fertilizer tended to improve the cooking quality of potatoes. All treatments produced an increase in top growth. When combined with superphosphate the three forms of potash tested were equally effective as sources of potash. Potash alone did not significantly increase yields.

Five minor elements, boron, zinc, manganese, copper, and iron, failed to increase potato yields significantly.

There was a definite residual effect of the fertilizer on the yield of spring grains which followed potatoes. Fertilizer recommendations for potatoes on the two soil groups are suggested.

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